UNIVERSITY OF LIVERPOOL

Year 2 Project

Infrared LED Electronic Harp Based On Arduino

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Abstract

This project designs and builds a new musical instrument that uses infrared light. The concrete performance in use is that the normal led glows when the IR photoresistor is not blocked between it and the IR led, while when the IR photoresistor is blocked between the two, the normal led goes out and the speaker emits the corresponding melody. Meanwhile, the main steps are as follows. (a) Connect the IR photoresistor to the normal led and connect it to the Arduino. (b) Connect the IR led to the power supply and connect it to the IR photoresistor one by one. (c) Connect the speaker to the Arduino and run the corresponding code. This project achieved the convenience of practical application of Arduino and completed the hardware and programming of the infrared electronic harp, basically achieving design goals. This report will briefly explain the design principles, circuit diagram and code, experimental steps, description of each device, analysis and discussion of the results and a final summary of this infrared electronic harp.

Declaration

I confirm that I have read and understood the University's definitions of plagiarism and collusion from the Code of Practice on Assessment. I confirm that I have neither committed plagiarism in the completion of this work nor have I colluded with any other party in the preparation and production of this work. The work presented here is my own and in my own words except where I have clearly indicated and acknowledged that I have quoted or used figures from published or unpublished sources (including the web). I understand the consequences of engaging in plagiarism and collusion as described in the Code of Practice on Assessment (Appendix L).

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Chapter 1

1. Introduction

1.1 background

The focus of this research is on an Arduino-based infrared electronic harp. The electronic harp is a new concept musical instrument that has emerged in recent years, using a light beam as a string attached to a sensor. The electronic harp is mostly based on a microcontroller, LEDs and related components to form a new concept electronic music device that imitates a traditional harp to play music. When the light beam in it is blocked, the sensor detects a change in the signal, which causes the electronic speaker to emit sound. The electronic harp is a fusion of modern electronic technology and music development, which greatly increases the interest in music performance and explores the future development of electronics and music.

In recent years, many people have explored the electronic harp. Most of these explorations have used laser components and stm series microcontrollers. One of the most famous French electronic music artists, jean-michel jarre, often uses a laser harp in his recitals, and it is one of the most popular features of his recitals. He is also credited with the rise of this instrument.

In these practices, the laser has its advantages, but the damage to the human eye is not negligible. This research has not yet been explored and this experiment will provide experience and guidance for an alternative implementation of the electronic harp. In this experiment, the circuit design issues associated with using infrared LEDs instead of laser LEDs and the code implementation issues associated with using arduino will be addressed. At the same time, this experiment will verify the feasibility and reliability of the infrared electronic harp. The focus will be on the testing of the infrared LED.

The following is the outline of this paper. In section 2, this experiment updates and designs the experimental methodology in light of the problems associated with the relevant protocol changes. In Section 3, the results of the experiments are presented and illustrated in relation to the tests carried out on the infrared electronic harp. Then, in section 4, the paper discusses the gains of this experiment and its limitations. Also, conclusions and future directions are provided.

Chapter 2

2. Materials and methods

2.1 Materials

In this project, the aim to use infrared LEDs instead of laser LEDs. and the assumptions about some of the things that may happen in the experiment are as follows, for the overall circuit redesign due to the use of different conventional components, for the handling of scattering and attenuation problems of infrared LEDs.

2.1.1 Infrared LED

Infrared diode, a diode made of a PN junction made of a material with high efficiency in infrared radiation (often GaAs), to which a forward bias is applied to inject current to excite infrared light. It has a narrow band distribution and is within the range that can be sensed by ordinary CCD black and white cameras. Its greatest advantage is that it can be completely red-storm free [4].

Infrared diodes are mostly used colorless transparent resin package or black, light blue resin package in three forms, colorless transparent resin package tube, can be observed through the resin material, if the tube core under a shallow disk, that is, infrared diodes, photodiodes and phototransistors without this shallow disk; if the dark resin package, can be used with the help of a multimeter R $\times$ 1k file to distinguish, infrared light-emitting diodes reverse resistance is usually hundreds of kilo-ohms to infinity, its forward resistance has 15 to 40kΩ between (depending on the different models and the degree of newness); and photodiode forward resistance is only about 10kΩ, phototransistor forward and reverse resistance are infinity (all for the value measured under shading conditions).

Infrared diode anode (P pole) voltage plus positive, cathode (N pole) voltage plus negative, this time the diode voltage added to the positive voltage, but also produce positive current, to provide the infrared light-emitting diode to launch the beam of energy, its light-emitting conditions and general light-emitting diode (LED), but infrared for invisible light. In general, the infrared light-emitting diode of gallium arsenide must be about 1V, while the red light-emitting diode of gallium cut-in voltage must be about 1.8V; green light-emitting diode cut-in voltage must be about 2.0V. When the added voltage exceeds the cut-in voltage, the current will rise rapidly, and the surrounding temperature on the diode's cut-in voltage is also very influential, when the temperature is higher, will make its cut-in voltage value lower, and vice versa, the cut-in voltage increases. Infrared light-emitting diode work in the reverse voltage, only a small leakage current, but the reverse voltage exceeds the collapse 4 collapse voltage, it will immediately produce a large amount of current, will make the components burned, the general infrared diode reverse withstand voltage value of about 3 ~ 6V, in the use of try to avoid having this situation occur.

2.1.2 Infrared photodiode

A photodiode is structurally similar to a semiconductor diode in that its core is a PN junction with photosensitive characteristics and has a one-way conductivity, so it needs to be coupled with a reverse voltage when working. When there is no light, there is a small saturation reverse leakage current, i.e. dark current, when the photodiode is cut off. When illuminated, the saturation reverse drain current increases greatly, forming a photocurrent, which varies with the intensity of the incident light. When the light irradiates the PN junction, it can make the PN junction produce electron-hole pairs, so that the density of a few carriers increases. These carriers drift at the reverse voltage, which increases the reverse current. Therefore the intensity of light can be used to vary the current in the circuit. Commonly available are the 2CU, 2DU and other series.

A photodiode is a semiconductor device that turns a light signal into an electrical signal. Its core part is also a PN junction, compared with ordinary diodes, the structural difference is that in order to facilitate the acceptance of incident light, the PN junction area is made as large as possible, the electrode area is as small as possible, and the junction depth of the PN junction is very shallow, generally less than 1 micron.

The photodiodes operate under reverse voltage. When there is no light, the reverse current is very small (generally less than 0.1 microamps) and is called the dark current. When there is light, the photons carrying energy enter the PN junction and pass the energy to the bound electrons on the covalent bond, causing some of the electrons to break free of the covalent bond, thus producing electron-hole pairs called photogenerated carriers.

They participate in the drift movement under the action of the reverse voltage, making the reverse current significantly larger, the greater the intensity of the light, the greater the reverse current. This property is called "photoconductivity". The current generated by a photodiode under normal illumination is called photocurrent. If a load is connected to the external circuit, an electrical signal is obtained from the load and this electrical signal changes accordingly with the light.

Photodiodes are light-sensitive devices that are widely used in electronic circuits. The difference between a photodiode and an ordinary diode with a PN junction is that there is a transparent window in the housing of the photodiode to receive light irradiation for photoelectric conversion, and the text symbol in the circuit diagram is usually VD.

2.1.3 Arduino nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P released in 2008. It offers the same connectivity and specs of the Arduino Uno board in a smaller form factor.

Arduino is a convenient and flexible, easy to get started open source electronic prototyping platform. It includes hardware (various models of Arduino boards) and software (ArduinoIDE). Developed by a European development team in the winter of 2005. Its members include Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino, David Mellis and Nicholas Zambetti and others.

It is built on an open source simple I/O interface version and has a Processing/Wiring development environment using a Java-like, C language. There are two main parts: the hardware part is the Arduino board that can be used to make circuit connections; the other is the Arduino IDE, the program development environment in the computer. User just write the program code in the IDE, upload the program to the Arduino board, and then the program will tell the Arduino board what to do.

Arduino can sense the environment through a variety of sensors, feedback, and influence the environment by controlling lights, motors, and other devices. The microcontroller on the board can be programmed through Arduino's programming language, compiled into a binary file, and burned into the microcontroller. Programming the Arduino is done through the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). An Arduino-based project can contain only Arduino, or it can contain Arduino and some other software running on a PC, which communicate with each other (e.g. Flash, Processing, MaxMSP) to implement it [1].

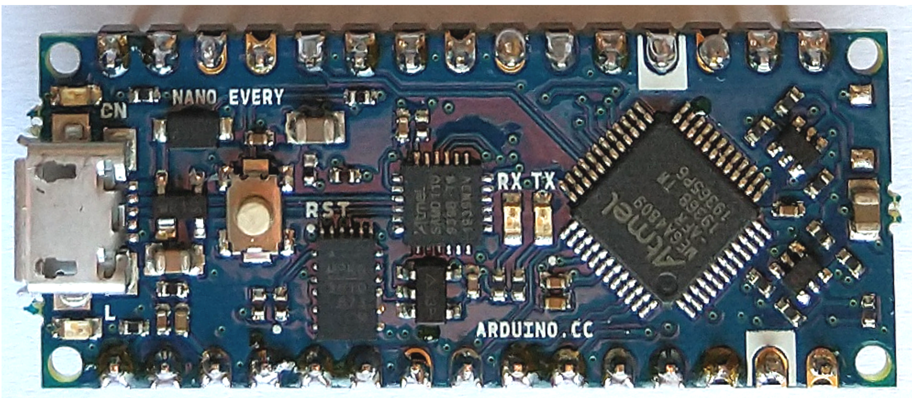

Figure 2.1 Top view of the Arduino nano

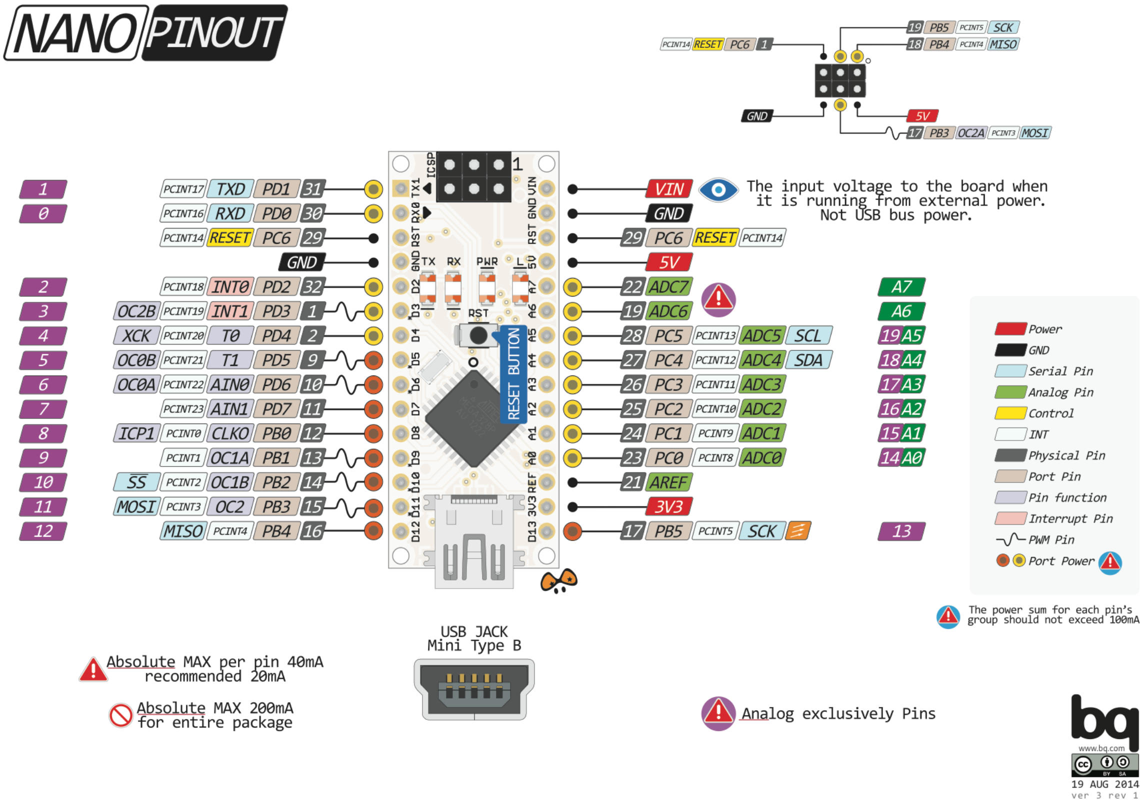

Figure 2.2 Arduino pinout

2.2 Methods

2.2.1 Circuit Design

In this experiment, different circuits were designed for different needs. For example, for the emitter side, this only need the eight infrared LEDs to work properly, without the need for fine-grained control. This was achieved by connecting the eight infrared LEDs in parallel and a 30 ohm resistor in series (according to the relevant formula) to a 4.5 V voltage source. For the receiver side, since this need to fine-tune the control of each group, the group chose to connect each group of IR photodiodes, normal LEDs and 10k ohm resistors in series, and then connect each group to a different pin on the Arduino.

The circuit simulation diagrams, schematic diagrams and the real circuit are as follows.

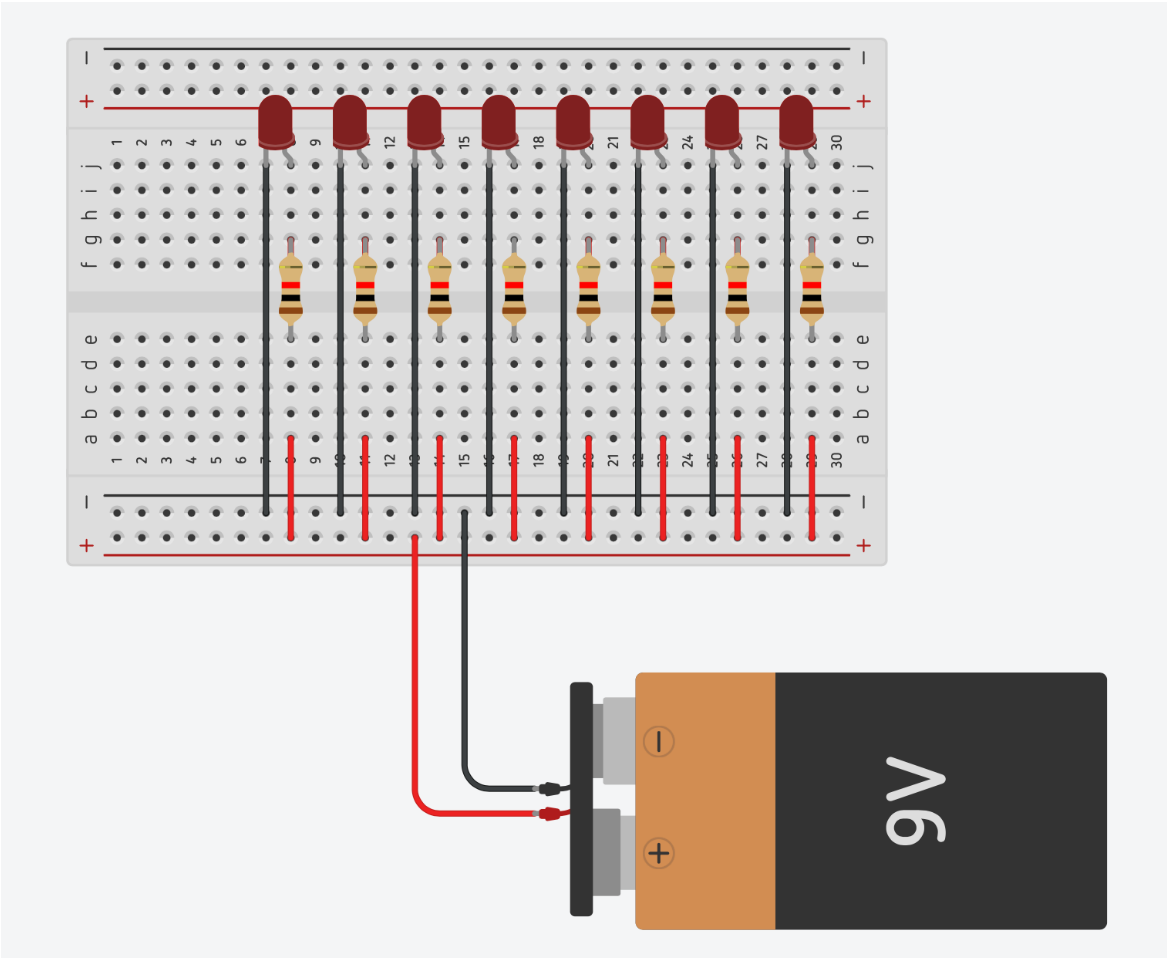

Figure 2.3 Simulated transmitter side

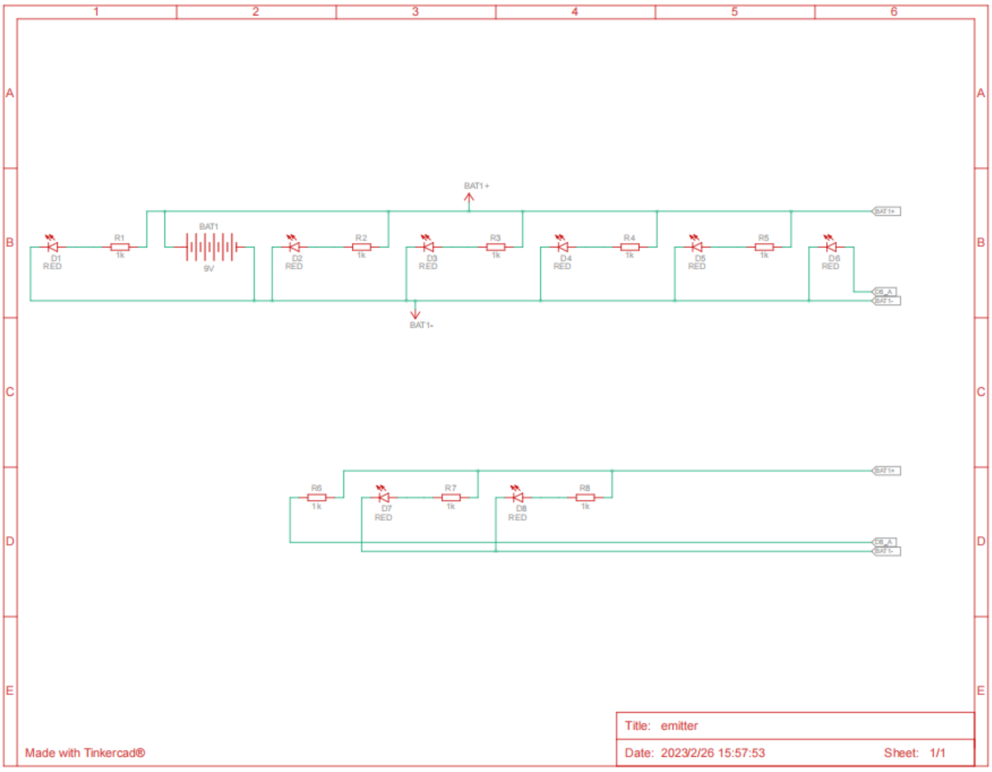

Figure 2.4 Schematic diagram of transmitter side

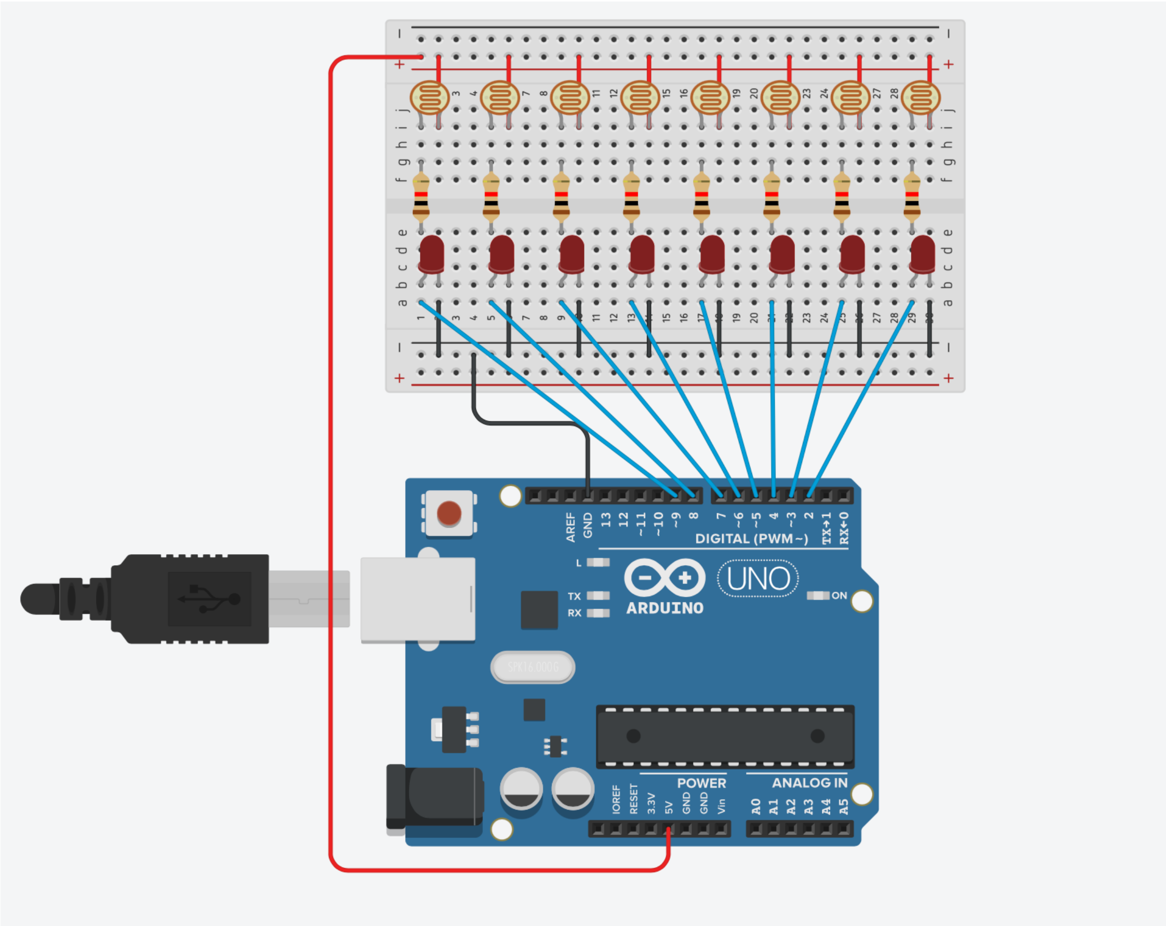

Figure 2.5 Simulated receiver side

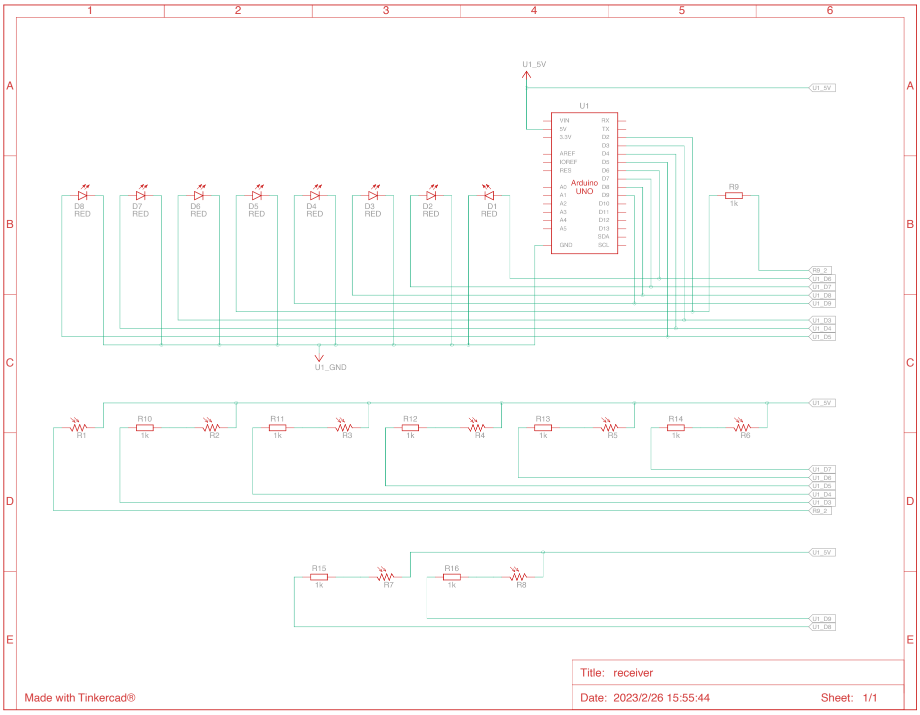

Figure 2.6 Schematic diagram of receiver side

2.2.2 Code

a. Global variables

At the beginning of the code, header file and variables used in the program are defined:

```
#include "pitches.h"
```

This header file includes the library with the frequencies of notes from B0 to DS8. In the project, C4 to C5 are used:

```
……
#define NOTE_C4   262
#define NOTE_D4   294
#define NOTE_E4   330
#define NOTE_F4   349
#define NOTE_G4   392
#define NOTE_A4   440
#define NOTE_B4   494
#define NOTE_C5   523
……
```

Two variables are defined as switches of two modes:

```
#define DEBUG_MODE 0   //Switch to debug mode to print out values of some important variables.
#define CHORD_MODE 0   //1: chord mode, 0: arpeggio mode
```

The first mode is DEBUG_MODE. When it is switched on, values of some variables will be printed through the serial to show whether the program is running normally, including how many notes are played and which notes are played. This mode is purposed to monitor the working status of the program and if the program cannot work as expectation, it can help find out where goes wrong quickly.

The second mode is CHORD_MODE. There is a limitation in the speaker that it can only produce a sound with a specific frequency. When there is only one note being played, corresponding frequency can be found in "pitches.h"; however, if several notes are played at the same time, it is hard to define its frequency, which means the speaker cannot play a chord. To solve this problem, group find out two methods to simulate or replace a chord. Switching to which method is decided by the value of CHORD_MODE and the working principles of two methods will be shown in detail later.

Three variables which can be changed to adapt to different needs are defined as:

```
#define speakerPin 12 //Control the pin which drives the speaker.
#define note_time 500   //Control the duration time of each note.
#define duration_time 500   //Control the duration time between notes.
```

Basic settings of notes and input sensor:

```
#define NOTE_RANGE 8   //Control the range of notes played in program.
const unsigned short note[NOTE_RANGE] = {NOTE_C4, NOTE_D4,
NOTE_E4, NOTE_F4, NOTE_G4, NOTE_A4, NOTE_B4, NOTE_C5};
//Control the specific notes played in program.
```

```
unsigned short note_num;   //Count the number of pins with LOW input.

unsigned short sensor_val[NOTE_RANGE];   //This array stores the signals from input pins.
```

Variables which can decide the order of notes when CHORD_MODE is 0:

```
unsigned short last_note = 0; //Store last played note.

unsigned short next_last_note;   //Record the last one of current input notes.

unsigned short median_note; //Record the median one of current input notes.

unsigned short median_note_position;   //Position of median note in sensor_val[] array.
```

General counters:

```
int i, j; //General counters.
```

b. Setup function

If DEBUG_MODE is switched on, initialize the serial:

```
#if DEBUG_MODE

Serial.begin(9600);

#endif
```

Set up D2 to D9 on the main board as input pins:

```
for(i = 2; i < 10; i++){
    pinMode(i, INPUT);
  }
```

c. Loop function

At the beginning of each loop, recorder for the number of notes and counter need to be reset:

```
note_num = 0; //Reset note_num before each loop.
j = 0;   //Reset counter.
```

Next, the board will read the signals from input pins and record the number of pins with LOW input:

```
for(i = 0; i < 8; i++){
 sensor_val[i] = digitalRead(i + 2);

//note_num counts how many strings are plucked / how manys notes are played at the same time.
 if(sensor_val[i] == LOW){
   note_num++;
   }
}
```

If note_num is 0, which means there is no note played, the program will junp back to the beginning of the loop and repeat reading pins until note_num is not 0. Otherwise, the number of notes will be recorded and form an array to store the pins with LOW input:

```
int melody[note_num];

median_note_position = (note_num / 2);   //Record the median position in the melody.

 //Store notes into the "melody" array
 for(i = 0; i < 8; i++){
    if (sensor_val[i] == LOW){
       melody[j] = note[i];

       if(j == median_note_position){
             median_note = i;   //Record note at median position of the melody.
       }

       if(j == (note_num -1)){
          next_last_note = i; //Record last note of the melody.
       }

       j++;
```

```
        }
    }
```

If there is only one note played, the board will send the frequency of the note to the speaker. After that, the program will jump back to the beginning of the loop.

```
    if(note_num == 1){
        tone(speakerPin, melody[0], note_time);
        delay(duration_time);
        noTone(speakerPin);
    }
```

If there is more than one note played, the value of CHORD_MODE will be judged and it will decide the way that the speaker handle several notes at the same time.

If CHORD_MODE is 1, the program will be switched to chord mode. In this mode, the frequency of each note will be sent to the speaker in order for a very short duration and the notes will be repeated for times (calculating by the set note_time and the number of notes) to simulate a chord. As the frequencies of notes in this program is from 262Hz to 523Hz, the period is from 1.91ms to 3.82ms. Therefore, the duration of each note is set as 50ms to ensure the integrity of notes. For example, if the user play “Do” “Re” “Mi” “Fa” at the same time, the speaker will produce a sound with “Do” tone for 50ms, then “Re” for 50ms, “Mi” for 50ms and “Fa” for 50ms. And these four steps will be repeated for 5 times:

```
    for( i = 0; i < (note_time / (50 * note_num) + 1); i++){
```

```
        for(j = 0; j < note_num; j++){
            tone(speakerPin, melody[j], 50);
            delay(50);
            noTone(speakerPin);
        }
    }
```

If CHORD_MODE is 0, the program will be switched to arpeggio mode. In this mode, the chord is replaced with an arpeggio, which means they will be played one by one. The order of the notes being played is decided by the median note of the input notes and the last note which player have played. If the median note is higher than the last note, the input notes will be played in an ascending order; otherwise, they will be played in a descending order. And after playing all the notes, the last_note variable will be updated. For example, if player play a “Do” and then play “Re” “Mi” “Fa” at the same time, it will be played as “Do” “Re” “Mi” “Fa”; and if player play a “La” and then play “Re” “Mi” “Fa” at the same time, it will be played as “La” “Fa” “Mi” “Re”. This function is purposed to make the notes sound more smoothly:

```
    if(median_note <= last_note){
        int temp = 0;

        for(i = 0; i < (note_num) / 2; i++){
            temp = melody[i];
            melody[i] = melody[note_num - 1 - i];
```

```
            melody[note_num - 1 - i] = temp;
          }
        }

        //Play the melody in the processed order and the last note will last
longer than previous ones.
        for(i = 0; i < note_num; i++){
          if(i == (note_num - 1)){
          tone(speakerPin, melody[note_num - 1], note_time);
          delay(duration_time);
          noTone(speakerPin);
          }
          else if(i < (note_num - 1)){
            tone(speakerPin, melody[i], note_time / 2);
            delay(duration_time / 2);
            noTone(speakerPin);
          }
        }
      }
      last_note = next_last_note; //Update last_note for next loop.
```

Chapter 3

3. Materials and methods

3.1 Revisiting the research aim

The aim of the project is to construct a laser harp with Arduino, infrared LEDs, infrared photoresistors and speaker. It is supposed to realize the function that with plucking the IR "string", the speaker will play corresponding notes.

3.2 Revisiting expanding methodology

To achieve the goal, the group designed a circuit. The circuit is divided into two parts: an emitter circuit and a receiver circuit. In the emitter circuit, a 4.5V voltage source is connected to the paralleled infrared LEDs as power supply. A 1kΩ resistor is also connected in the circuit as protection. In the receiver circuit, an infrared and a normal LED makes up a receiver module. Eight receiver modules and the Arduino board are connected in parallel. The power supply for the circuit is another 4.5V voltage source. To connect the two parts, pairs of infrared LEDs and photoresistors are fixed head-to-head in parallel to provide a stable transmission for IR signal.

3.3 Specific results in detail

At the end of the project, the group have constructed a complete circuit and realized expected functions. The infrared photoresistors are connected with normal LEDs and the Arduino board. When the IR signal is blocking by finger, the speaker will play a corresponding note. At the same time, the corresponding LED will be turned off as a visual indication. And if more than one signal is blocked, the speaker will play a simulated chord or an arpeggio according to preset mode.

3.4 Comparison with results in other research

Compared to traditional laser harp projects, the group use IR modules to replace laser LED. Traditional laser LED has a better visual performance, and its light is more concentrated than IR signal. However, there exist a potential danger that it may injury eyes with improper operation. As a result, the group replace laser LED light with IR signal to ensure safety. Normal LEDs are used as compensation for the visual performance. Besides, due to lower power supply, IR is more sustainable than traditional laser.

3.5 Problems with results

However, there are still some problems in the project. First, as IR signal is invisible, it is hard to confirm whether the infrared LED is in alignment with the photoresistor. Besides, infrared LEDs in other lines may influence the photoresistor. As a result, the harp may not be as sensitive as expected sometimes. Second, due to the limited function of the speaker, the group cannot produce a real chord and have to simulate or replace it with programming.

3.6 Possible implications of results

In conclusion, the project is an innovative infrared LED electronic harp based on Arduino. Replacing traditional laser LED with IR elements, it realizes basic functions of laser harp as well as improve the safety and sustainability.

Chapter 4

4. Materials and methods

4.1 Project Review and Summary of Key Findings

4.1.1 Work results

This project achieved good results and met the intended expectations. As the name of the project suggests, the ultimate goal is to have eight pairs of musical instruments composed of infrared emitters and photodiode receivers and electronic components such as Arduino chips and speakers, and these components, their duties are: the ones that make up the 'strings' are the infrared emitters and photodiodes, while the Arduino is the main board and the speakers play the sound thus completing a musical instrument. There are many parts to the outcome of this project. Overall the goal of the infrared electronic piano was achieved, completing a finished musical instrument that can play simple tracks manually. Separately, in the infrared and photodiode parts, the relationship between them was successfully explored, and how to make them interact in a useful enough way that they can influence each other to change the voltage of the circuit, and the voltage of the resistor as a sensing part of the whole project. They succeeded in achieving this goal by being able to sense and recognize objects by their occlusion, thus changing the voltage. The Arduino part, which successfully forms the 'brain' of the project, controls the entire circuit through the Arduino's voltage measurement of the eight pins, and the speaker is a feedback device, and the

Arduino makes different sounds through the different detection of the pins, forming the eight rhythms that make the entire The device becomes a complete musical instrument.

4.1.2 Key findings and self-evaluation

There were very many discoveries during the experiment that allowed the experiment to be carried out and completed in its entirety. For example, in the sensor part, the infrared and photodiode circuit, instead of using a photodiode as a receiver, an IR receiver was used at the beginning, but during the experiment, the IR receiver, due to its special characteristics, could receive the IR infrared, but it showed very weakly on the ohmmeter, so the voltage change was also very weak, which was not enough to so that the Arduino can successfully identify the high and low voltage, so that the whole sensor function can not be used, so after various adjustments and methods, such as increasing the voltage of the circuit, reducing the range between IR and IR receiver and other methods, it is still decided to replace the device with a photodiode, which is simpler and more sensitive to meet the needs of the project. In this experimental process, if no testing was done directly, it would have led to the failure of the whole project because the Arduino could not be recognized without this discovery, so this discovery brought the whole project closer to the original goal. During the experiment, in the IR part, it was always difficult to know how to determine if they were emitting infrared light, but then it was discovered that the determination was done by the other half of the l part which is the receiving part, so that it was discovered if the IR part was working properly, and there was also an opportunity to adjust the resistor and thus the voltage which means adjusting the intensity of the infrared light. There were many other discoveries throughout the experiment, and they all contributed greatly to the overall project being able to accomplish the original goal.

For the self-evaluation of the whole project, the group think that the whole project is not much different from the expected result, and almost 100% of the expectation is accomplished. However, there are still some shortcomings, the project has some limitations, due to time, equipment and other factors, the group can only make a simple IR Harp, which can only have one range, so it can only be called a simple instrument, playing simple music. If group could use radium for the completion of the project, the spacing between the strings of the Harp would not be a problem, because the radium power is so much more powerful than the IR, so this limits the size of the whole Harp and the ease of playing. For now, the project can be used as a toy for children to inspire their musical talent and play simple music, or as a simple auxiliary instrument to play in a band or other music production.

4.2 Project relevance in the real situation

4.2.1 Condition of the project in progress

Throughout the course of the project, the group are still very satisfied with the completion of the project, which successfully met the expectations. Because the expectation was to make a Laser Harp that could make sound, but due to the dangers of laser, the group changed it to an IR harp and chose to use a safe and more reasonable way for the school project to be completed without changing the basic method. If the group use radium, without protection, it can cause harm to the human body, especially to the eyes, causing irreversible and serious damage, even with protective equipment, so it is obvious that the group cannot use it, while infrared is a relatively safe ray that is not visible to the naked eye and can be very sensitive to the receiver's response, so it is a very good choice to use it instead.

4.2.2 Achievements and knowledge gained in the project

For the whole project the group used the knowledge learnt for the design and calculation of the circuits and the application and use of diodes. In terms of the application of practical skills, this project has enhanced the application level and allowed us to apply the learning in practice. We have independently designed and engineered the project, programmed the code, built the circuit and tested the whole project as a practical application of the knowledge. The regulations were also complied with and safety and environmental standards were met. The uncertainties in the technology have been suitably adjusted and pointed out, as well as areas for future improvement.

The development of electrical engineering students requires an adaptive environment that promotes the learning independence of engineering students. The requirements of an accredited engineering project are first described and then it is explained how the Independent Open Learner model is used to promote reflection, planning, formative assessment and learner independence. For the whole project, the requirements for professional engineering competence in the UK have been met as far as possible so that there will be competence in future working life as well.[2]

4.3 Limitations of the project and application in reality

4.3.1 Limitations

There is still a lot of room for improvement in the whole project and for further work. In the infrared and photodiode part, they may be affected by more than one corresponding infrared due to the dispersion of infrared, they may affect each other and cause the Arduino can not read the level properly, so the group need to think of some ways to improve, such as replacing the infrared with stronger power, or redesigning the layout again, using some materials that can block other infrared as a baffle, so that they do not affect each other, and other methods.

4.3.2 Applications

This project, which can be applied in many ways. The most important areas are in the field of music and early childhood education. It is an infrared Harp, which is harmless and allows for simple music playing. In the field of music, it can be used for daily musical entertainment and can be taken out for fun when bored. Even in advanced music, it is possible to improve the code to make it a more advanced instrument, so that it can be played more often and be useful in music. The electronic harp may also replace the traditional harp in the future, but it is unlikely that the original harp will be eliminated, because the electronic harp does not guarantee the purity and integrity of the music, so there are still many possibilities in the field of music [3]. And for children's education, where music is nurtured from an early age and people need musical talent, this harmless and simple instrument is the most child-friendly and will therefore be of great use. It can entertain people, develop their musical cells and increase their interest in music.

4.4 Conclusion

Overall, the project has created a new, environmentally friendly and very safe laser harp that avoids the harm caused by lasers and gives music lovers and children music initiators a new and refreshing instrument. The project overcame most of the difficulties, such as infrared scattering and power supply, to achieve the desired results. However, there are still some areas where the project could be improved, such as replacing the existing speakers with midi-programmable and controllable speakers, which would allow the instrument to play a wider range of tones and a wider range of voices, resulting in better musical results.

Commercially, the project could be of great use in both the musical and educational fields and has a very large market.

Reference List

[1]“A000005 - Single Board Computer, Arduino Nano, Atmega328, 22 I/O, 32kb flash, 2KB SRAM, 1KB EEPROM,” onecall. [Online]. Available: https://onecall.farnell.com/arduino/a000005/arduino-nano-evaluation-board/dp/1848691?st=a000005. [Accessed: 17-Mar-2023].

[2]Bull, S. and Gardner, P. (2010) ‘Raising learner awareness of progress towards UK-SPEC learning outcomes’, *Engineering education (Loughborough)*, 5(1), pp. 11–22. Available at: https://doi.org/10.11120/ened.2010.05010011.

[3]Kost, A. (2016) ‘Lariviere on the laser harp?’, *The American harp journal*, p. 40–.

[4]“OFL-5102 - infrared emitter, 940 nm, 10 °, T-1 3/4 (5mm), 15 MW/SR,” onecall. [Online]. Available: https://onecall.farnell.com/multicomp/ofl-5102/infrared-emitter-940nm-t-1-3-4/dp/1716710?st=ir+emitter. [Accessed: 17-Mar-2023].

Appendices

Appendix A

Y2 project (ELEC222/ELEC273) – *Role allocation (responsibility matrix)*

Notes:

- ***Assessors will request to see this sheet in the bench inspection day.***
- ***See overleaf for details on titles and associated roles and responsibilities.***

	Member Name	**Title(s)**
1	Chen Liang	Project Manager Designer Implementer/Developer Technical Writer
2	Kai Ma	Designer Technical Writer
3	Bohao Li	Implementer/Developer Technical Writer
4	Xinyi Wang	Designer Implementer/Developer

Responsibility Matrix

KEY:

R – Responsible (accountable) for completion of task. (Task can be delegated to this person.)

S – Supports task.

C – Requires communication about the task.

Title	**Project Activity**				**Deliverables**			
	Requirements/ Scope	**Design**	**Implementing**	**Testing**	**Poster**	**Blog**	**Bench**	**Report**
Project Manager	R	C	S	S	S	S	S	S/R
Designer	C	R	S	S	S	S	S	S
Implementer/ Developer	C	S	R	S	C	C	R	S
Technical Writer	C	S	S	S	R	R	C	R

Typical Roles

Title	Role	Responsibilities
Project Manager	Responsible for developing, in conjunction with the supervisor, the project scope. The Project Manager ensures that the project is delivered on time and to the required standards.	• Managing and lead the project team. • Managing the coordination of the partners and the working groups.
Designer	Designing the system (the circuit, the code, etc.).	• Creating the required block diagrams, circuit diagrams, flow charts, etc.
Implementer/Developer	Implementing the suggested design	• Connecting the systems/circuit • Writing the code
Technical Writer	Documenting the project progress and deliverables	• Recording and maintaining all meeting logs • Updating the logbook. • Creating project blog • Creating project poster • Writing project report

Y2 project (ELEC222/ELEC273) - *Attendance record*

Notes:

- ***This sheet should be updated by group members weekly when they meet to discuss the project.***
- ***Assessors will request to see this sheet in the bench inspection day.***

	Member name	**Attended the weekly meeting? (Yes/No)**					**Comments**
		Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	
1	Chen Liang	Y	Y	Y	Y	Y	Attend weekly
2	Kai Ma	Y	Y	Y	Y	Y	Attend weekly
3	Bohao Li	Y	Y	Y	Y	Y	Attend weekly
4	Xinyi Wang	Y	Y	Y	Y	Y	Attend weekly

Y2 project (ELEC222/ELEC273) - *Contribution to project deliverables*

Notes:

- ***Assessors will request to see this sheet in the bench inspection day.***
- ***Typical deliverables include: Bench, Poster, Blog, Report, Code, Circuit, etc.***

	Member name	**Deliverable(s)**	**Comments**
1	Chen Liang	Bench Circuit Report	Managed the entire project, designed and built the project circuit.
2	Kai Ma	Bench poster Report	Collaborated on the design of the circuit and designed the poster.
3	Bohao Li	Bench Blog Report	Assisted in building and testing circuits, wrote and maintained blogs.
4	Xinyi Wang	Bench Code Report	Wrote and tested project code.

Year 2 Project (ELEC222/273) –*Log Book*

Week 1

Date: 03/02/2023 Supervisor: Dr. Naser Sedghi

Project Title: IR LED Electronic Harp

Student Names /Attendees:	1.Chen Liang	2.Bohao Li
3.Kai Ma	4.Xinyi Wang	5.

Weekly record:

In this week, we decided to do the Infrared LED harp to be the Year 2 Project. We built the circuit for the experiment on Tinkercad and did the experimental component shopping.

The main components needed are an Arduino board, LED lights, infrared transmitter, photo diodes and a speaker.

The design principle of this IR LED Electronic Harp is as follows, it is a string with eight pairs of infrared emitters and infrared receivers, and uses Arduino as the main board of the chip to read the signal, when the photo diode can receive the infrared signal, Arduino will read the high level, the speaker does not sound. On the contrary, when there is an object blocking, similar to a person plucking the 'string', Arduino will read the low level, thus controlling the speaker to make a sound.

Year 2 Project (ELEC222/273) –*Log Book*

Week 2

Date: 10/02/2023 Supervisor: Dr. Naser Sedghi

Project Title: IR LED Electronic Harp

Student Names /Attendees:	1.Chen Liang	2.Bohao Li
3.Kai Ma	4.Xinyi Wang	5.

Weekly record:

This week we have the components we needed to build the main part of the laser harp. According to the simulation in Thinkercad last week, we built the circuit about the IR led part and the IR receiver part.

We use the 5V to be the supply voltage. And we known the rated current of the IR is 20mA, so we chose the 1000 ohms of resistance in the circuit. Then we make them to be the same line, which make sure receiver can get the infrared ray from the IR. And we used the ohmmeter to connect the resistance at the receiver end. When it can receive infrared ray, the circuit will go on and the resistance will get voltage. The ohmmeter can see obvious changes from small to large. But in experiment, it didn't work. We can not see the voltage from the ohmmeter.

We used many ways to find the reasons of that, such like changing resistance to make sure it’s not too low to get low voltage, and using higher voltage to increase the IR power. In finally, we made them work, but it only got a very small change. With our analysis, the receiver is probably not the component we need, so we decided to buy the photo diode to be the receiver part, and in next week, we can use them in experiment.

Year 2 Project (ELEC222/273) –*Log Book*

Week 3

Date: 17/02/2023 Supervisor: Dr. Naser Sedghi

Project Title: IR LED Electronic Harp

Student Names /Attendees:	1.Chen Liang	2.Bohao Li
3.Kai Ma	4.Xinyi Wang	5.

Weekly record:

In last week's experiment the circuit we built for the IR and receiver did not work, in this week we updated the components and turned the receiver a photo diode for the experiment.

We connected the circuit and used a 300 ohms resistor to protect the circuit and connected an ohm meter for measurement.

This time the replacement was successful, the photo diode successfully received the IR signal and showed a high voltage on the voltmeter, thus completing the fundamental construction. The next step is to program the Arduino and connect the speaker and the bulk of the system is complete.

After testing it was found that the Arduino and Speaker were damaged and needed to be replaced with new components for experimentation.

Year 2 Project (ELEC222/273) –*Log Book*

Week 4

Date: 24/2/2023 Supervisor: Dr. Naser Sedghi

Project Title:IR LED Electronic Harp

Student Names /Attendees:	1.Chen Liang	2.Bohao Li
3.Kai Ma	4.Xinyi Wang	5.

Weekly record:

During the week we replaced the new Arduino and Speaker, connected them to the IR and photo diode circuits and tested them. Made it work successfully. And finished the posters, blogs and other work this week.

Finally, we practiced and rehearsed our presentation and perfected our paper work, such as poster presentations, in preparation for bench inspections.

As the supervisor of this group prefers handwritten weekly meeting logs, the weekly meeting logs for this project will be presented in the form of scanned images.

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 1*

Date: 2023/2/3 Supervisor: Dr. Naser Sedghi

Project Title: Infrared LED laser harp

Student Names /Attendees:	1.Chen Liang	2. Bohao Li
3. Xinyi Wang	4.Kai Ma	5.

Summary of week's activities:

This week our group has been working on the Year 2 Project. It was decided that we would design a Laser Harp, an electronic harp based on an Arduino, infrared sensing and LED lights, which visually looks like a harp and consists of a frame and a set of 8 'strings'. Each "string" is an individual beam of downward-pointing laser diodes. By plucking the 'strings', the Arduino board constantly reads the sensors and if it detects a 'pluck' event, it makes a sound.
Once the task was defined, the components needed were discussed and selected. Initial simulations of the circuit were also carried out on the Tinkercad.

Problem, issues and concerns:

For the components, we are not yet sure about the suitability of the selected components and the suitability of the components after real experiments. Only preliminary simulations have been carried out on the Tinkercad simulation, and the complete presentation of the circuit will take a little time.

Tasks for next week/Actions for next meeting:

Before the next meeting we will complete the design of the circuit, simulated on the Tinkercad.If we've got the components we need, then next week's lab day we'll get to work building the circuit and testing it for problems running in real-world situations and summarising them.

Supervisor use only

Progress Assessment: □ Unsatisfactory □x Satisfactory □ Good

Comments/Recommendations:

The students have changed the project, but they are committed to compensate the delay and finish the project on time.

Year 2 Project (ELEC222/273) – *Supervisor meeting* – Week 2

Date: 2023/2/10 Supervisor:Dr. Naser Sedghi

Project Title: Infrared LED laser harp

Student Names /Attendees:	1.Chen Liang	2.Xinyi Wang
3.Bohao Li	4.Kai Ma	5.

Summary of week's activities:
This week we received the components we needed to build the main part of the project, the infrared led with the infrared receiver harp. We also tested each of the IR led and IR receiver to make sure they were usable. We checked out the literature to understand the routine code for the arduino nano and the routines for the df mp3 player.

Problem, issues and concerns:
A rather obvious problem is that the pins of the midi control board seem to need soldering, and we are not familiar with how to write midi-related code. And, if we want to control 8 infrared receivers and 8 infrared leds for indication at the same time, then maybe the arduino interface is not enough.

Tasks for next week/Actions for next meeting:

Next week's work is the midi section, i.e. the circuit building for the audio output section. And, we need to code and test the arduino part to control the IR receiver.

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☑ Satisfactory ☐ Good

Comments/Recommendations:
The students need to finish the essential parts of the project first, and they can improve it when they have enough time.

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 3*

Date: 2023/2/17 Supervisor: Naser Sedghi

Project Title: Infrared LED laser harp

Student Names /Attendees:	1. Chen Liang	2. Bohao Li
3. Xinyi Wang	4. Kai Ma	5.

Summary of week's activities:
This week we have built on the previous week's improvements to the transmitter and receiver side of the circuit. After building the circuit we hooked it up to Arduion and tested it. And finished the code work on the mp3 part.

Problem, issues and concerns:
The main problem is that the ir receiver only generates a voltage change of about 0.2V when receiving infrared light or not, and the arduino does not recognise such a small voltage change.

Tasks for next week/Actions for next meeting:
Next week we will be tackling the arduino's recognition of voltage changes. In the meantime, we will put all the parts together and test them to achieve our desired goal.

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☐ Satisfactory ☑ Good

Comments/Recommendations: The students have tried building notes and also detecting the light signal. It seems that playing a chord is not possible with the Arduino speaker, The students can play single notes at a time or mimic the chord.

Year 2 Project (ELEC222/273) – *Supervisor meeting – Week 4*

Date: 2022/2/26 Supervisor: Dr. Naser Sedghi

Project Title: Infrared LED laser harp

Student Names /Attendees:	1. Chen Liang	2. Bohao Li
3. Xinyi Wang	4. Kai Ma	5.

Summary of week's activities:
This week we have successfully connected the ir module to the arduino board. We used two cell boxes (each can supply 4.5V voltage) to supply power for emitter and receiver module and we improved our circuit. Now the arduino board can distinguish whether the ir signal of each pair of ir module is blocked and record the status as LOW or HIGH.

Problem, issues and concerns:
Because of improper input voltage during debugging. ~~out~~ our speaker is burnt out. As a result, we haven't test ~~the circuit~~ whole circuit. Besides, two LEDs ~~~~ do not work and these components are temporarily replaced by wires.

Tasks for next week/Actions for next meeting:

In next week, we are going to change the speaker and the LEDs, completing our circuit. A final test will be done to confirm the project can work as expectation. For ~~ab~~ the rest of the week, we will prepare for the bench inspection.

Supervisor use only

Progress Assessment: ☐ Unsatisfactory ☐ Satisfactory ☑ Good

Comments/Recommendations: The students have done a good job and have finished all the tasks of the project. Hopefully they will receive the speaker module to have a good presentation.

Appendix B

Name	Chen Liang	Kai Ma	Xinyi Wang	Bohao Li
Contribution	31%	23%	23%	23%
Details	Manage the project; Design and build the circuit; Wrote the conclusion section of the report, revised and quality controlled the report in general	Collaborate on the design of the circuit; Design the poster; Complete the introduction and circuit methodology part of the report	Write and test the code; Complete the code methodology part of the report	Assist in building and testing circuit; Write and maintain the blog Complete the results and discussion part of the report

Appendix C

Source Code

```
#define NOTE_B0  31
#define NOTE_C1  33
#define NOTE_CS1 35
#define NOTE_D1  37
#define NOTE_DS1 39
#define NOTE_E1  41
#define NOTE_F1  44
#define NOTE_FS1 46
#define NOTE_G1  49
#define NOTE_GS1 52
#define NOTE_A1  55
#define NOTE_AS1 58
#define NOTE_B1  62
#define NOTE_C2  65
#define NOTE_CS2 69
#define NOTE_D2  73
#define NOTE_DS2 78
#define NOTE_E2  82
#define NOTE_F2  87
#define NOTE_FS2 93
#define NOTE_G2  98
#define NOTE_GS2 104
#define NOTE_A2  110
```

```
#define NOTE_AS2 117
#define NOTE_B2  123
#define NOTE_C3  131
#define NOTE_CS3 139
#define NOTE_D3  147
#define NOTE_DS3 156
#define NOTE_E3  165
#define NOTE_F3  175
#define NOTE_FS3 185
#define NOTE_G3  196
#define NOTE_GS3 208
#define NOTE_A3  220
#define NOTE_AS3 233
#define NOTE_B3  247
#define NOTE_C4  262
#define NOTE_CS4 277
#define NOTE_D4  294
#define NOTE_DS4 311
#define NOTE_E4  330
#define NOTE_F4  349
#define NOTE_FS4 370
#define NOTE_G4  392
#define NOTE_GS4 415
#define NOTE_A4  440
#define NOTE_AS4 466
#define NOTE_B4  494
#define NOTE_C5  523
#define NOTE_CS5 554
#define NOTE_D5  587
#define NOTE_DS5 622
```

```
#define NOTE_E5  659
#define NOTE_F5  698
#define NOTE_FS5 740
#define NOTE_G5  784
#define NOTE_GS5 831
#define NOTE_A5  880
#define NOTE_AS5 932
#define NOTE_B5  988
#define NOTE_C6  1047
#define NOTE_CS6 1109
#define NOTE_D6  1175
#define NOTE_DS6 1245
#define NOTE_E6  1319
#define NOTE_F6  1397
#define NOTE_FS6 1480
#define NOTE_G6  1568
#define NOTE_GS6 1661
#define NOTE_A6  1760
#define NOTE_AS6 1865
#define NOTE_B6  1976
#define NOTE_C7  2093
#define NOTE_CS7 2217
#define NOTE_D7  2349
#define NOTE_DS7 2489
#define NOTE_E7  2637
#define NOTE_F7  2794
#define NOTE_FS7 2960
#define NOTE_G7  3136
#define NOTE_GS7 3322
#define NOTE_A7  3520
```

```
#define NOTE_AS7 3729

#define NOTE_B7   3951

#define NOTE_C8   4186

#define NOTE_CS8 4435

#define NOTE_D8   4699

#define NOTE_DS8 4978




#include "pitches.h"


#define DEBUG_MODE 0   //Switch to debug mode to print out values of variables during programming.

#define CHORD_MODE 0   //1: chord mode, 0: arpeggio mode


#define speakerPin 12 //Control the pin which drives the speaker.

#define note_time 500   //Control the duration time of each note.

#define duration_time 500   //Control the duration time between notes.


#define NOTE_RANGE 8   //Control the range of notes played in program.

const unsigned short note[NOTE_RANGE] = {NOTE_C4, NOTE_D4, NOTE_E4, NOTE_F4, NOTE_G4,

NOTE_A4, NOTE_B4, NOTE_C5}; //Control the specific notes played in program.

unsigned short note_num;   //Count the number of pins with LOW input.

unsigned short sensor_val[NOTE_RANGE];   //This array stores the signals from input pins.


//Variables which can decide the order of notes when CHORD_MODE is 0.

unsigned short last_note = 0; //Store last played note.

unsigned short next_last_note;   //Record the last one of current input notes.

unsigned short median_note; //Record the median one of current input notes.

unsigned short median_note_position;   //Position of median note in sensor_val[] array.


int i, j; //General counters.
```

```
void setup() {
  #if DEBUG_MODE
  Serial.begin(9600);
  #endif

  //Setup input pins
  for(i = 2; i < 10; i++){
    pinMode(i, INPUT);
  }
}

void loop() {
  note_num = 0; //Reset note_num before each loop.
  j = 0;   //Reset counter.

  // Read signals from input pins.
  for(i = 0; i < 8; i++){
    sensor_val[i] = digitalRead(i + 2);

    //note_num counts how many strings are plucked / how manys notes are played at the same time.
    if(sensor_val[i] == LOW){
      note_num++;
    }
  }

  //Print the value of note_num for debugging.
  if(note_num != 0){
    #if DEBUG_MODE
    Serial.print("note_num: ");
```

```
Serial.println("note_num: "note_num);
#endif

int melody[note_num];

median_note_position = (note_num / 2);   //Record the median position in the melody.

//Store notes into the "melody" array
for(i = 0; i < 8; i++){
  if (sensor_val[i] == LOW){
    melody[j] = note[i];

    if(j == median_note_position){
      median_note = i;   //Record note at median position of the melody.
    }

    if(j == (note_num -1)){
      next_last_note = i; //Record last note of the melody.
    }

    j++;
  }
}

#if DEBUG_MODE
for(i = 0; i < note_num; i++){
  Serial.print(i);
  Serial.print("\t");
  Serial.println(melody[i]);
}
```

```
#endif

//If there is only one note input, play it for preset seconds.
if(note_num == 1){
   tone(speakerPin, melody[0], note_time);
   delay(duration_time);
   noTone(speakerPin);
}

#if CHORD_MODE
for( i = 0; i < (note_time / (50 * note_num) + 1); i++){
   for(j = 0; j < note_num; j++){
      tone(speakerPin, melody[j], 50);
      delay(50);
      noTone(speakerPin);
   }
}


#else //In this mode, when there are various input, the notes will be played one by one.

//If the median note of the melody is lower than last played note, reverse the order of notes, which may make the
melody sound more smooth.
if(median_note <= last_note){
   int temp = 0;

   for(i = 0; i < (note_num) / 2; i++){
      temp = melody[i];
      melody[i] = melody[note_num - 1 - i];
      melody[note_num - 1 - i] = temp;
```

```
      }
    }

    //Play the melody in the processed order and the last note will last longer than previous ones.
    for(i = 0; i < note_num; i++){
      if(i == (note_num - 1)){
      tone(speakerPin, melody[note_num - 1], note_time);
      delay(duration_time);
      noTone(speakerPin);
      }
      else if(i < (note_num - 1)){
        tone(speakerPin, melody[i], note_time / 2);
        delay(duration_time / 2);
        noTone(speakerPin);
      }
    }

    last_note = next_last_note; //Update last_note for next loop.
    #endif
  }
}
```